Potential of Airborne Lidar Observations of Water Vapour Transport

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Martin Wirth, Stephan Rahm

THORPEX European Regional Meeting, Karlsruhe, 26.5.2011

HALO: The New German Research Aircraft

maximum altitude 15.5 km

maximum range 10000 km

flight duration 8-10 hours

maximum payload 3 tons

6 viewports for lidar instruments

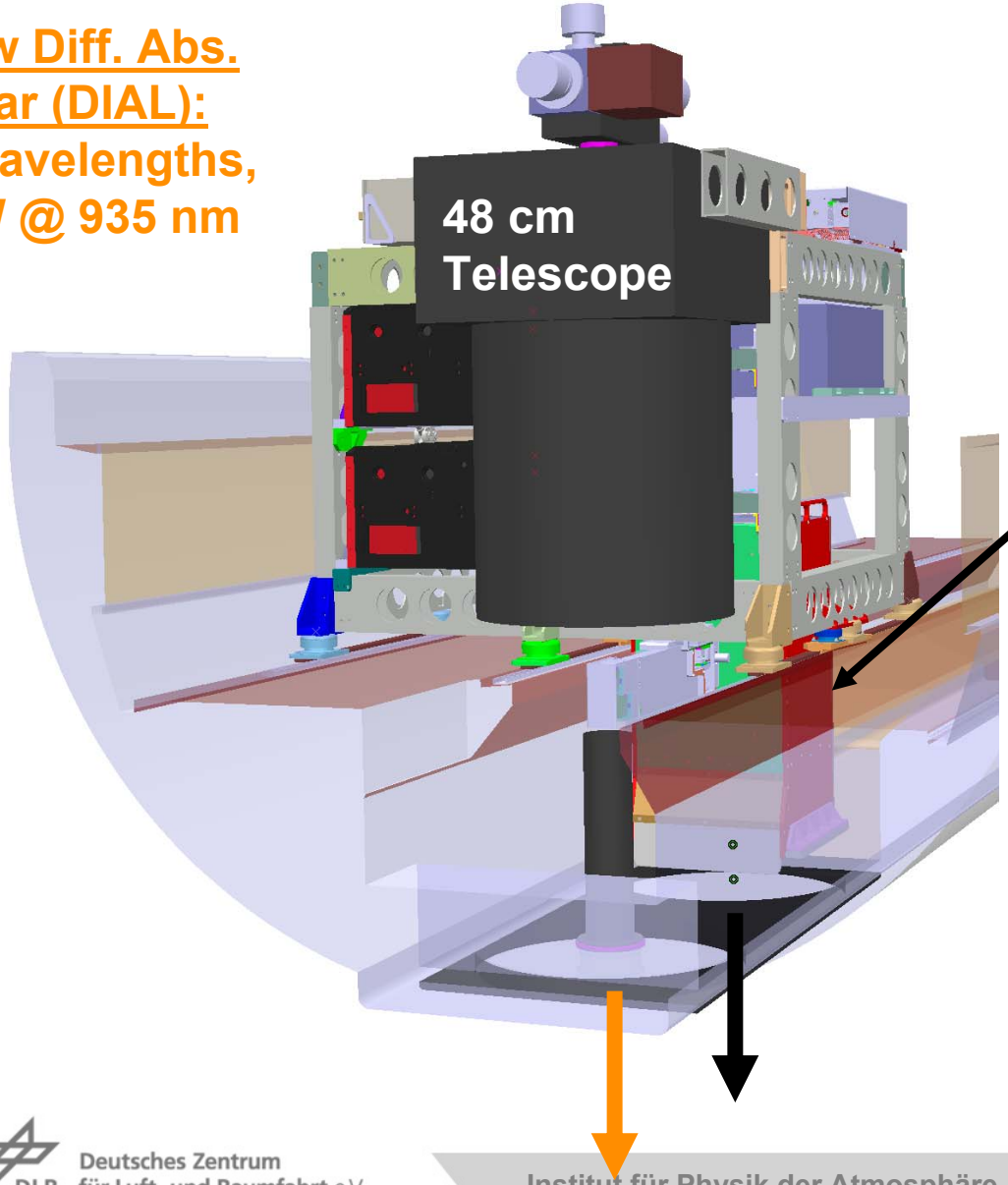
dropsondes: p, T profiles

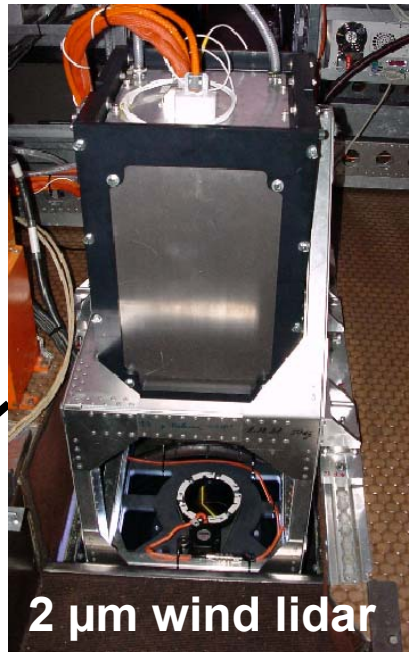
DIAL: H_2O, aerosols

Doppler lidar:
nadir: vertical wind,
scanning: hor. wind

Water Vapour and Wind Lidars: Own Developments

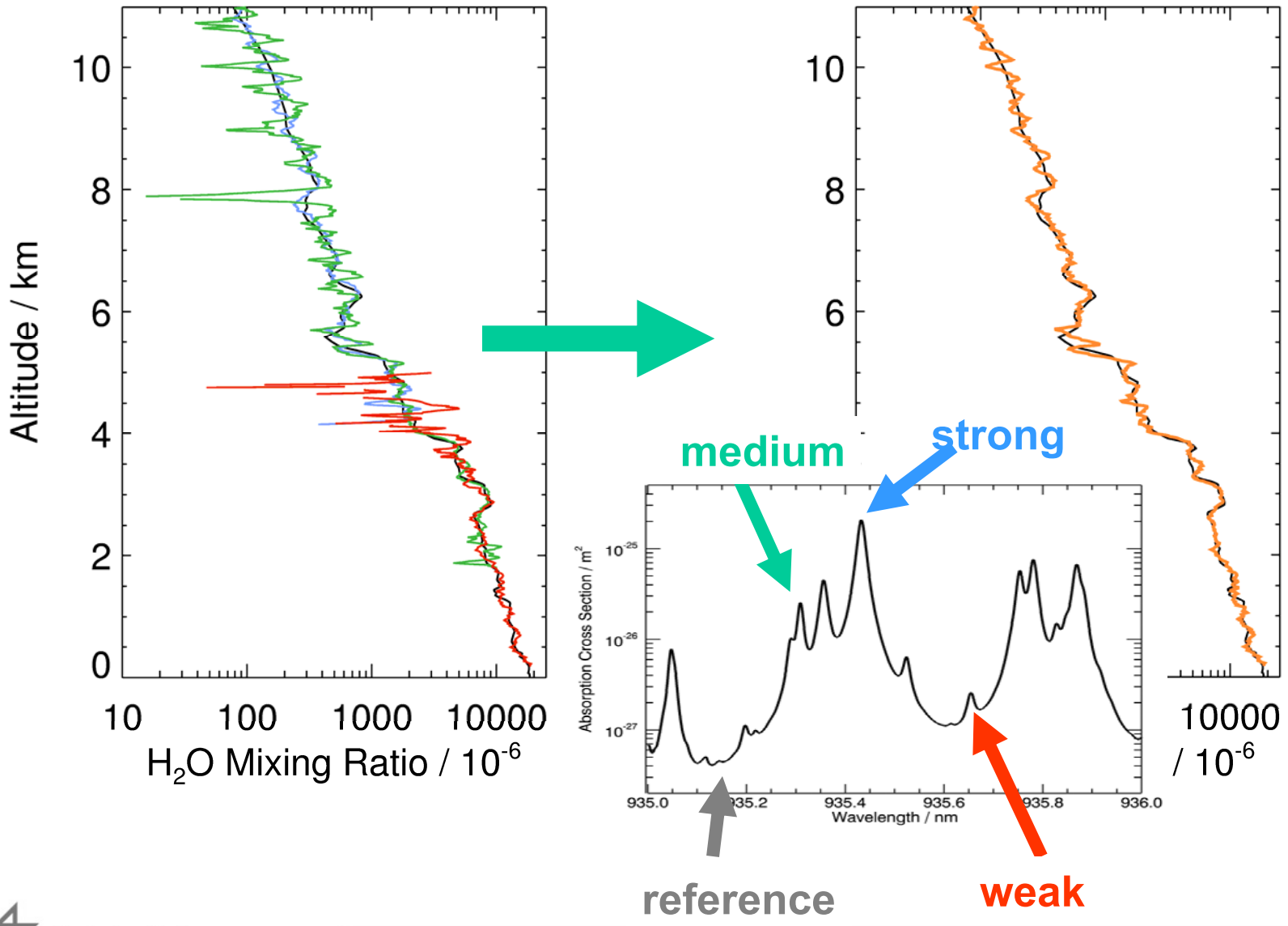
New Diff. Abs. Lidar (DIAL):
4 wavelengths, 8 W @ 935 nm





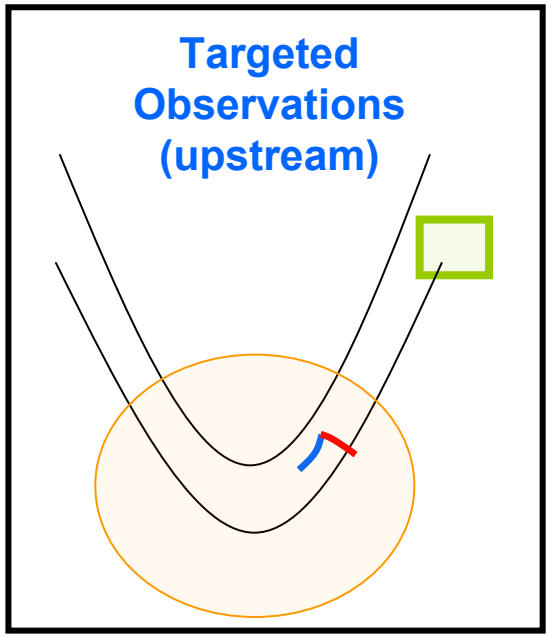
Wirth et al., Appl. Phys. B, 2009
Kiemle et al., JTech, 2007
Schäfler et al., JTech, 2010
Kiemle et al., QJRMS, 2011
Schäfler et al., QJRMS, 2011

Full tropospheric profile by three line combination



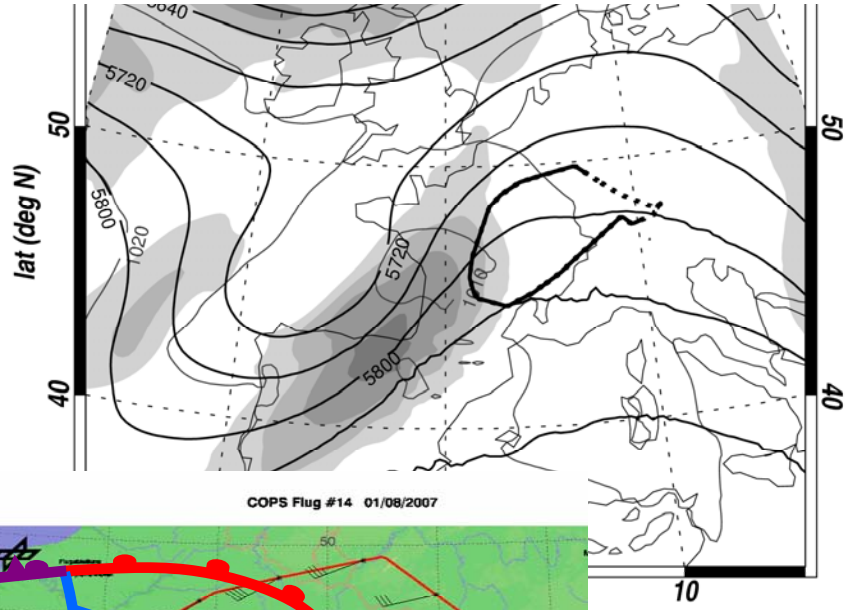
E-TReC 2007: European Thorpex Regional Campaign

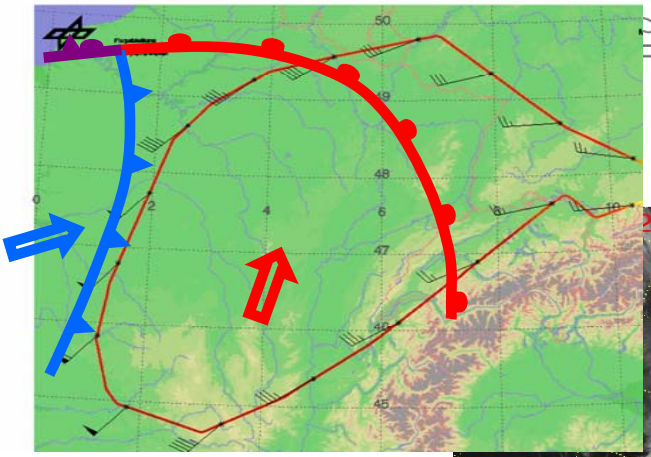
Mission Objectives



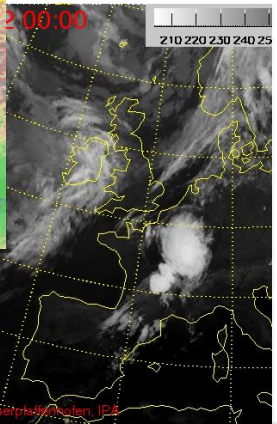
Perform targeted measurements across upstream sensitive regions over SW-Europe and quantify humidity advection into the COPS area.

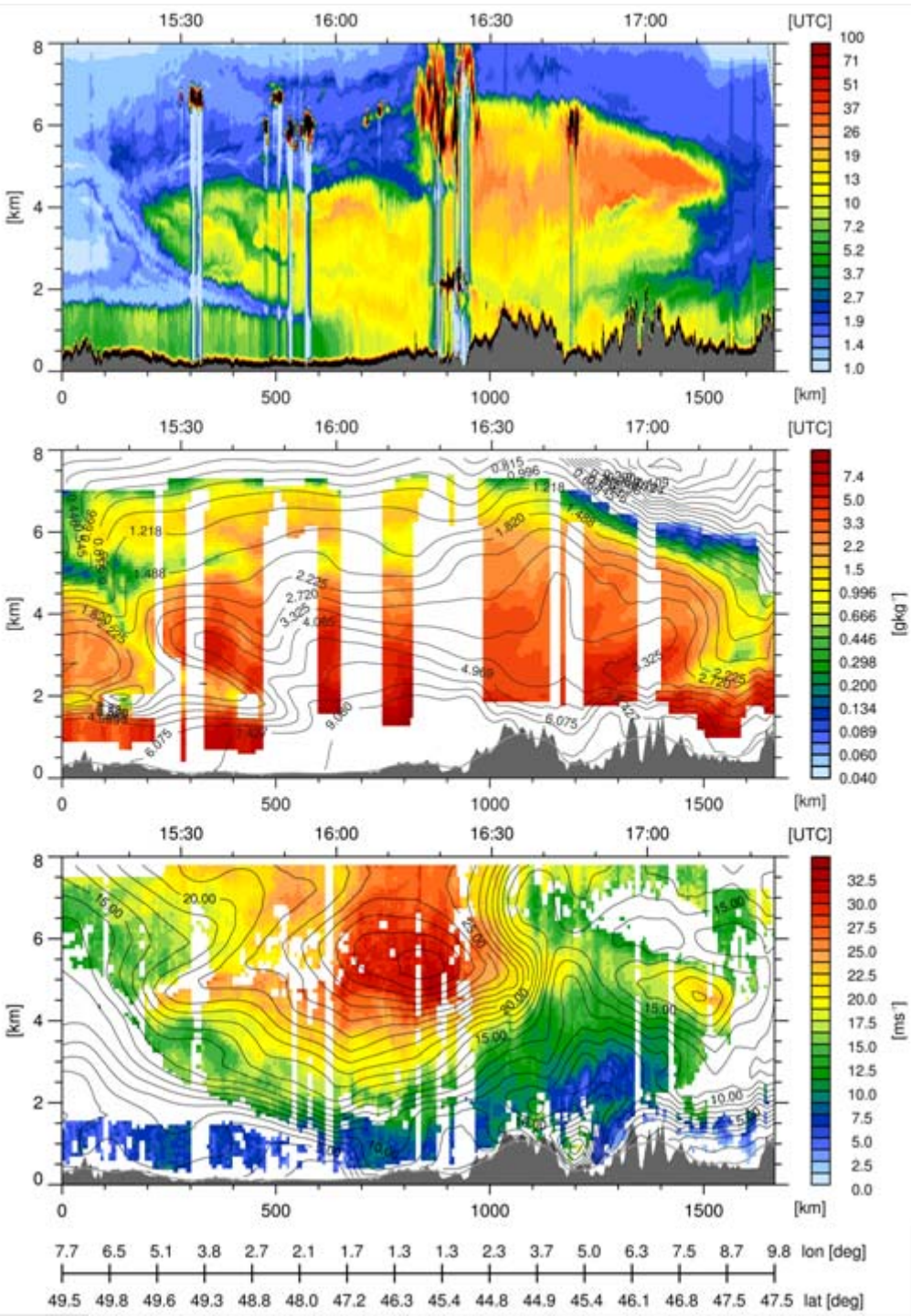
COPS-ETReC
1 August 2007





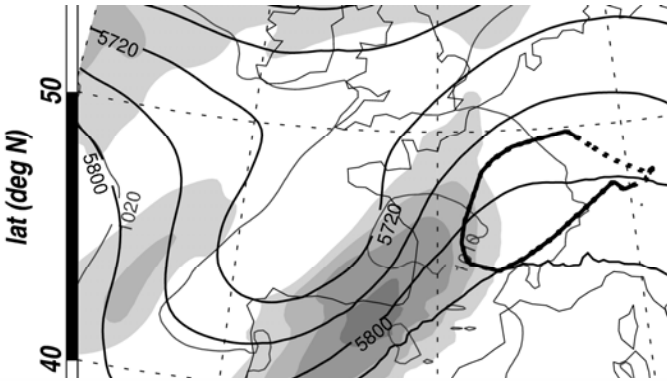
(m/s)

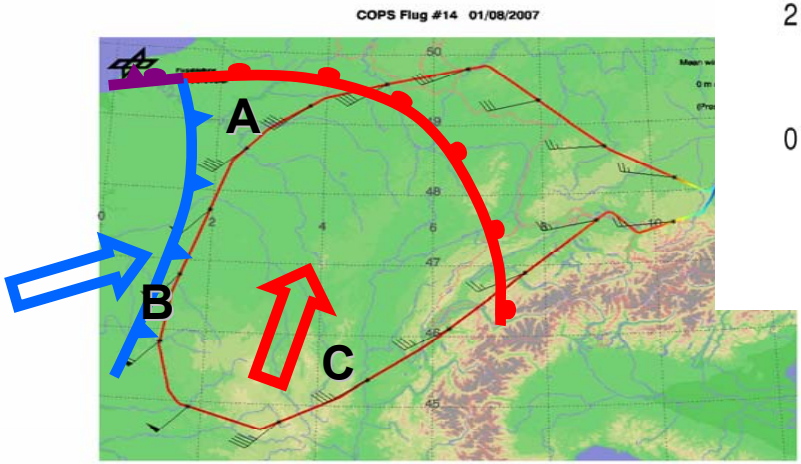


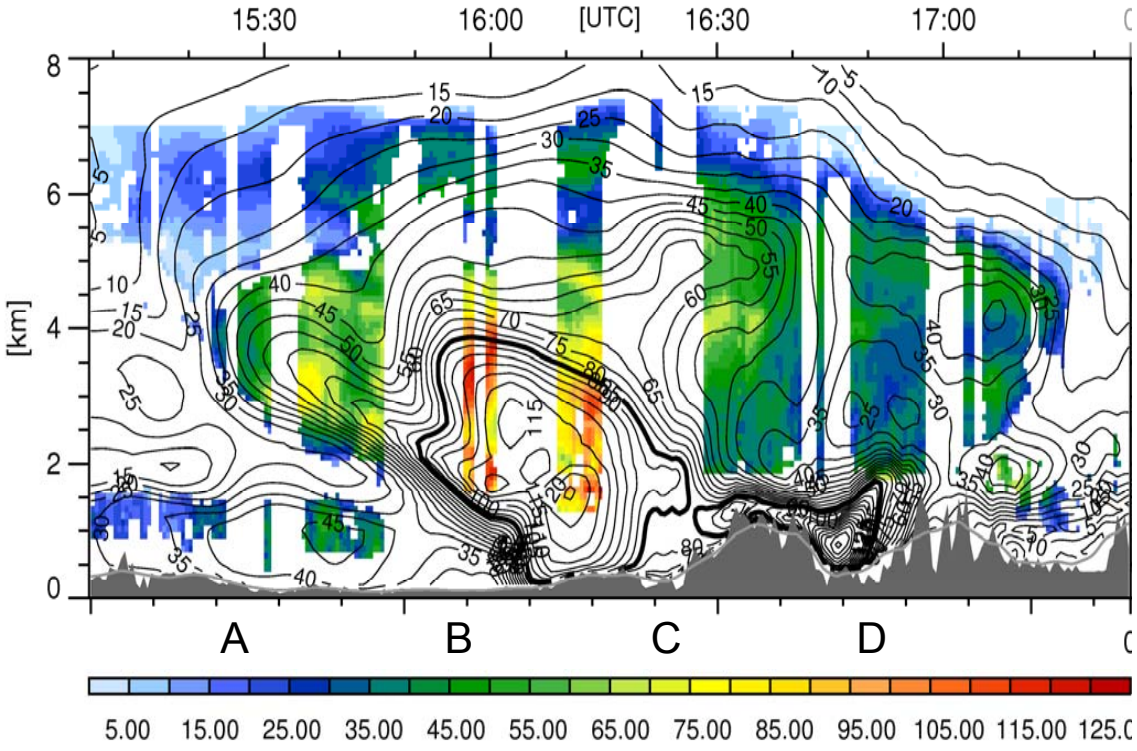


DLR Deutsches Zentrum für Luft- und Raumfah
in der Helmholtz-Gemeinsch

E-TReC 2007: Pre-convective Water Vapour Transport



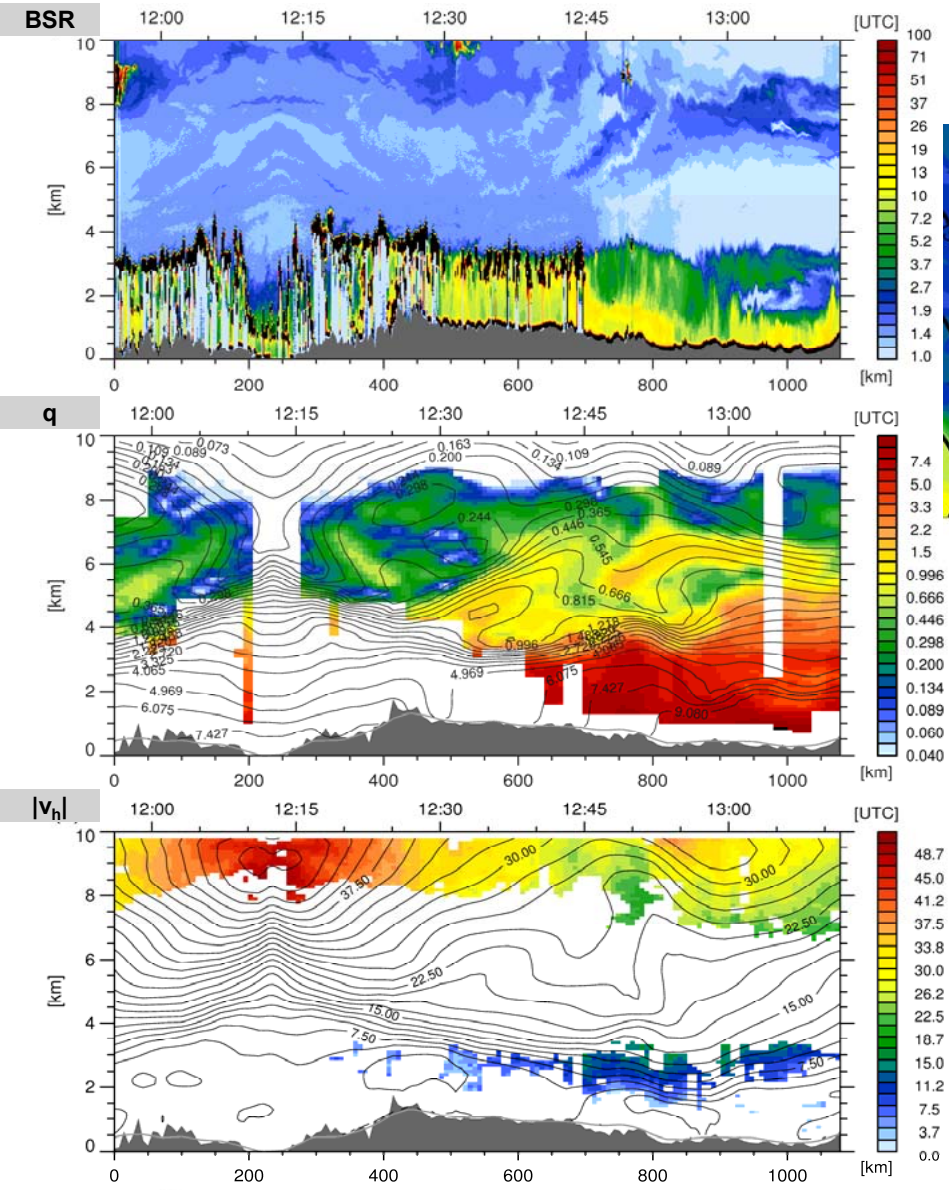


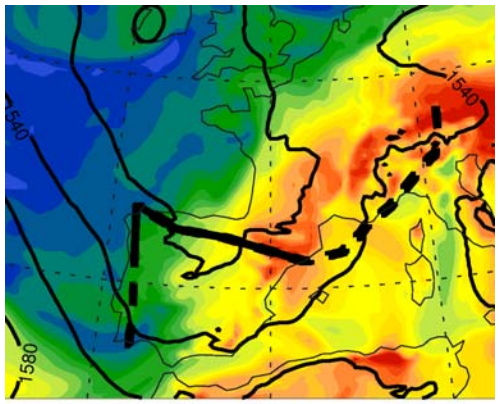


$q \cdot |v_h|$ in g/kg · m/s
Lidar obs: colors, ECMWF analysis: lines

Schäfler A, Dörnbrack A, Kiemle C, Rahm S, Wirth M., 2010: Tropospheric Water Vapour Transport as determined from Airborne Lidar Measurements, *J. Atmos. Oceanic Technol.*, **27**, 2017-2030.

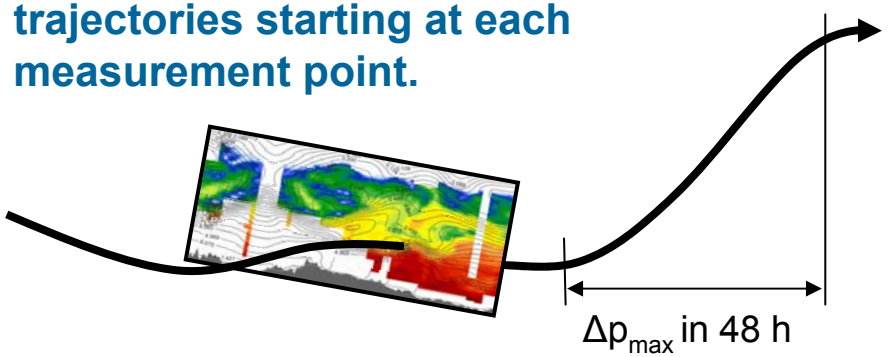
Flights Across Warm Conveyor Belts: COPS/ETReC Case Study 19.7.2007



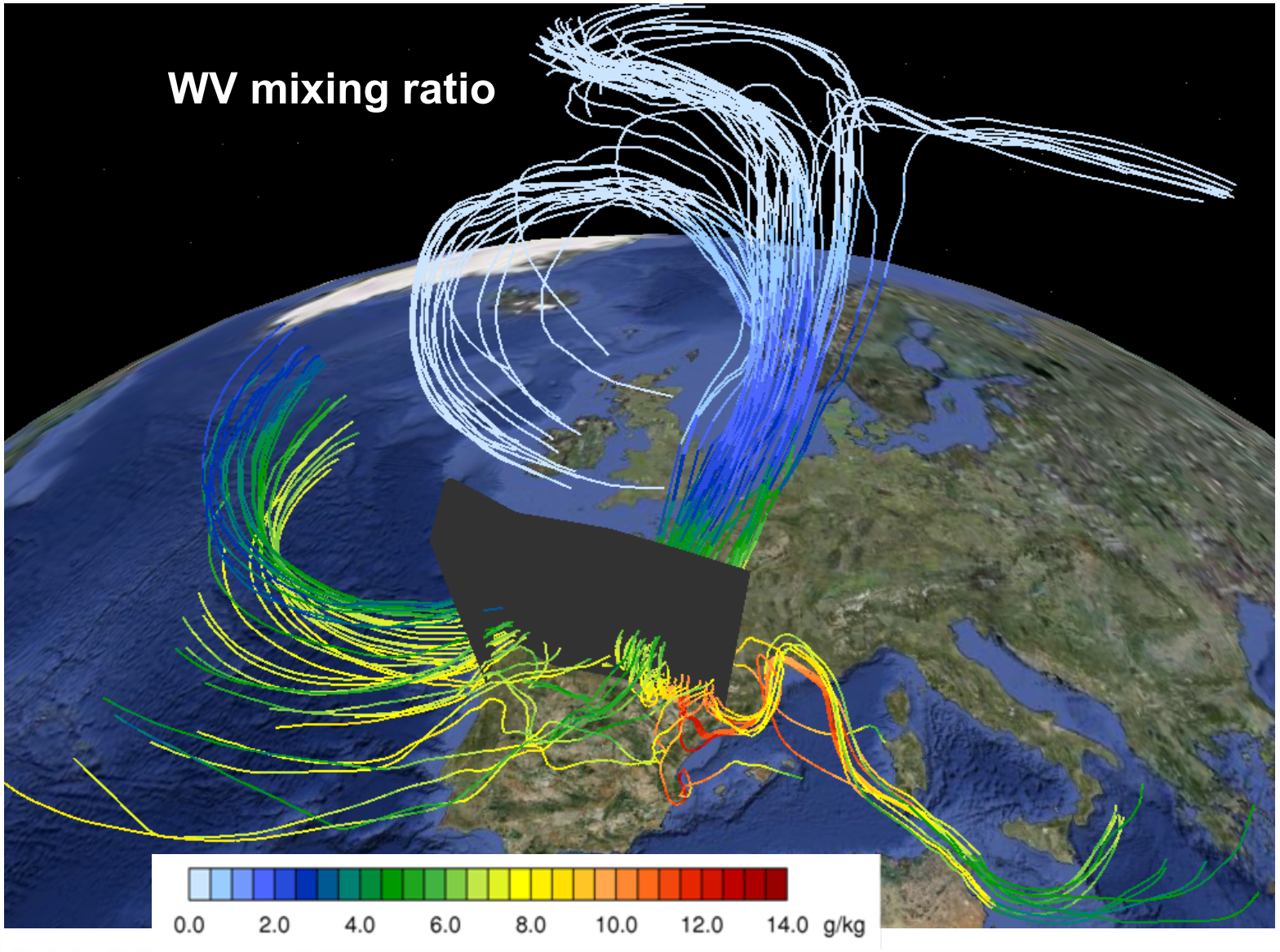


Where are the lidar WCB observations?
When did the air ascend?

→ Calculate forward and back trajectories starting at each measurement point.

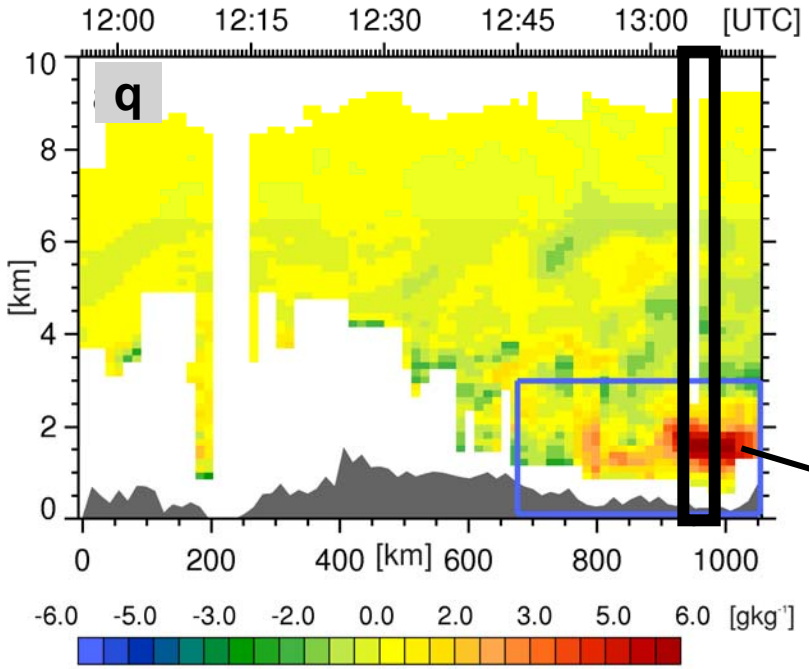


COPS Case Study 19. 7. 2007: WCB Structure



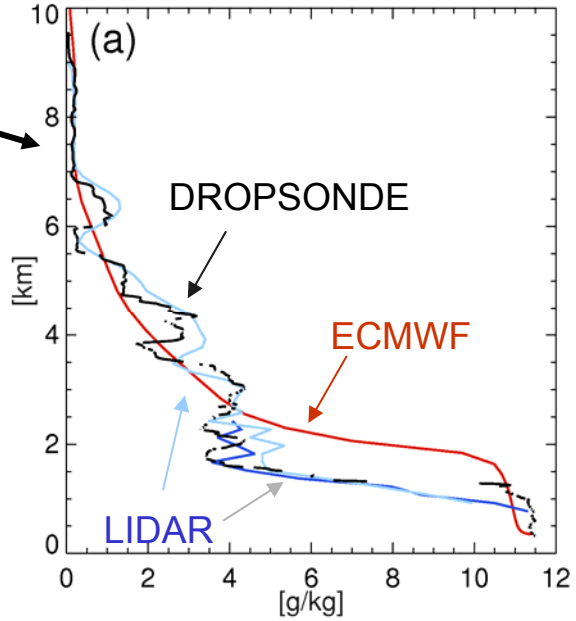
COPS Case Study 19. 7. 07: ECMWF Overestimates WCB Humidity Inflow

ECMWF - Lidar obs:

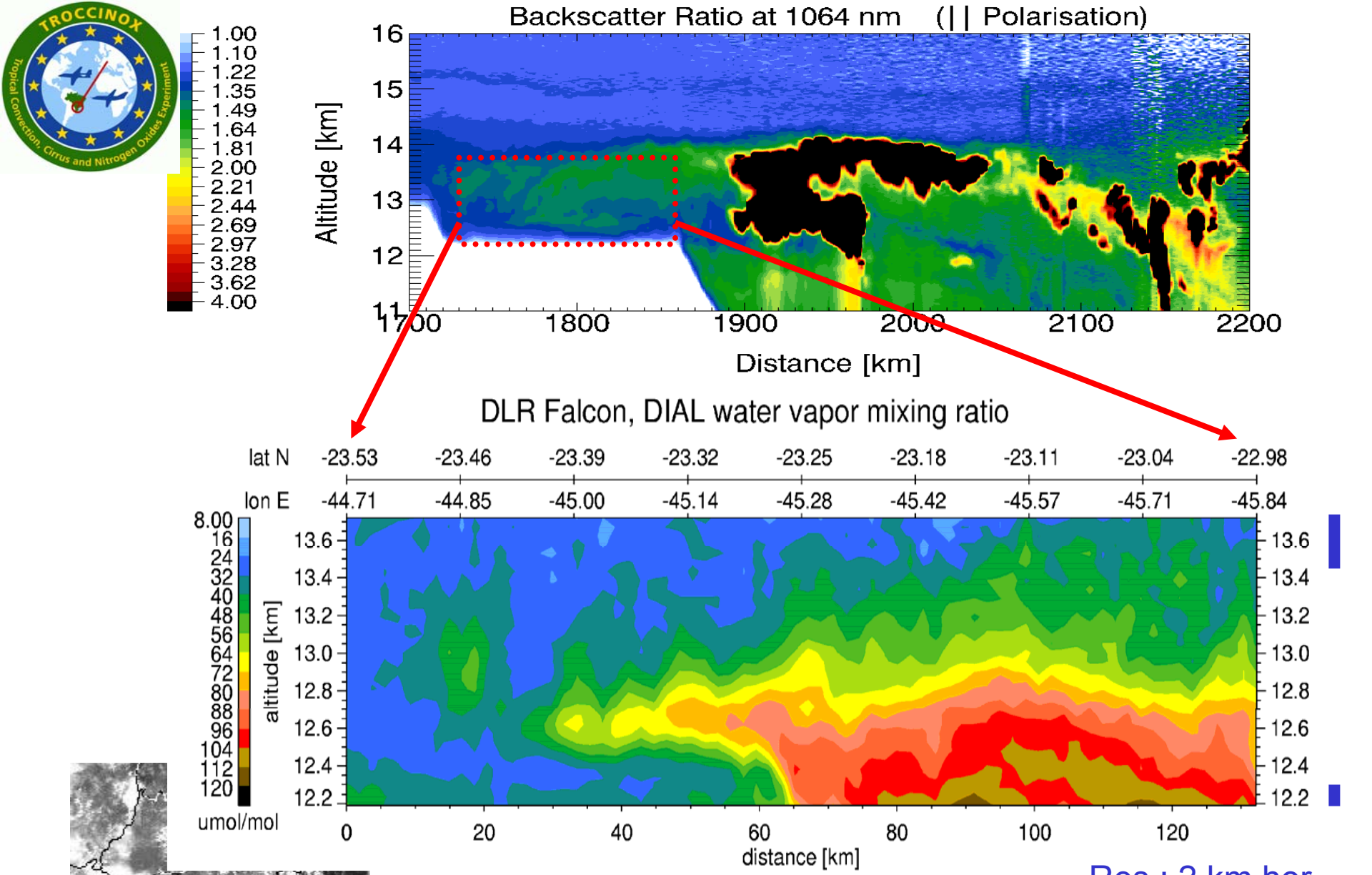


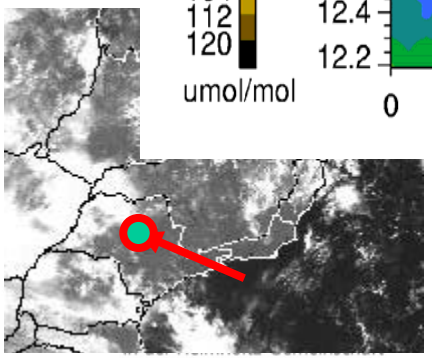
→ **mean bias in WCB inflow: ~ 1 g kg^{-1} (14 %)**

→ **max. bias: 7 g/kg (100 %)**



Schäfler, A., A. Dörnbrack, H. Wernli, C. Kiemle and S. Pfahl, 2010: Airborne Lidar observations in the inflow region of a warm conveyor belt. *Quart. J. Roy. Meteorol. Soc.*, accepted March 2011



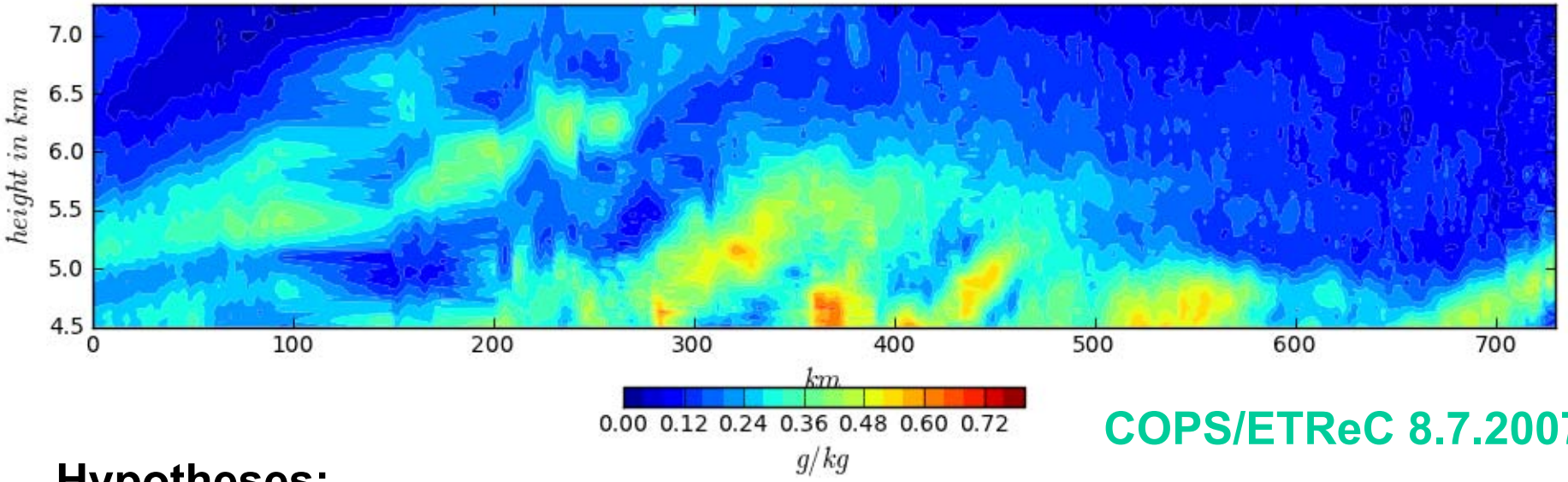


Tropical Deep Convection Outflow, Brazil, 2005

Res.: 2 km hor.,

100 - 300 m vert.

Water Vapour Variability in the Free Troposphere

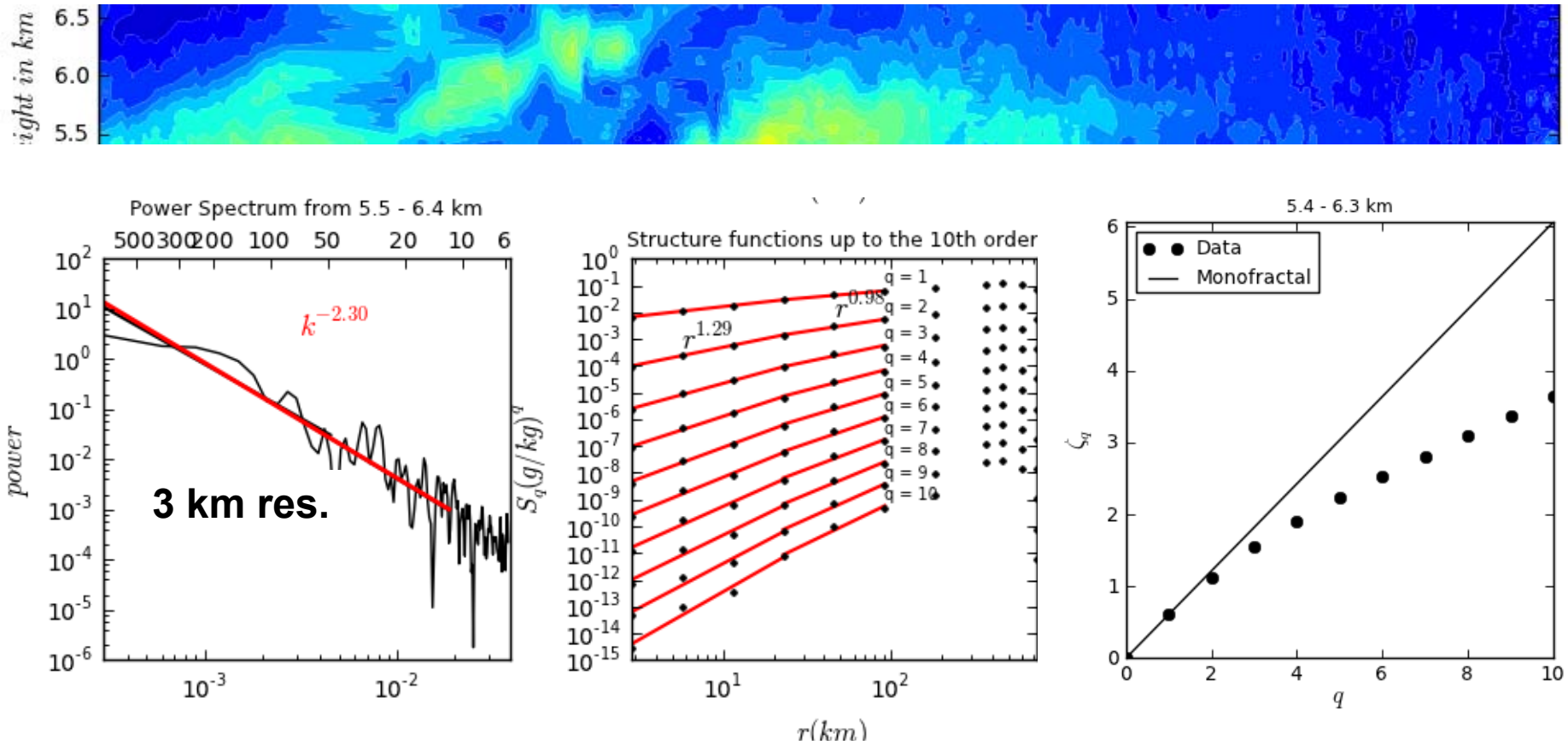


COPS/ETReC 8.7.2007

Hypotheses:

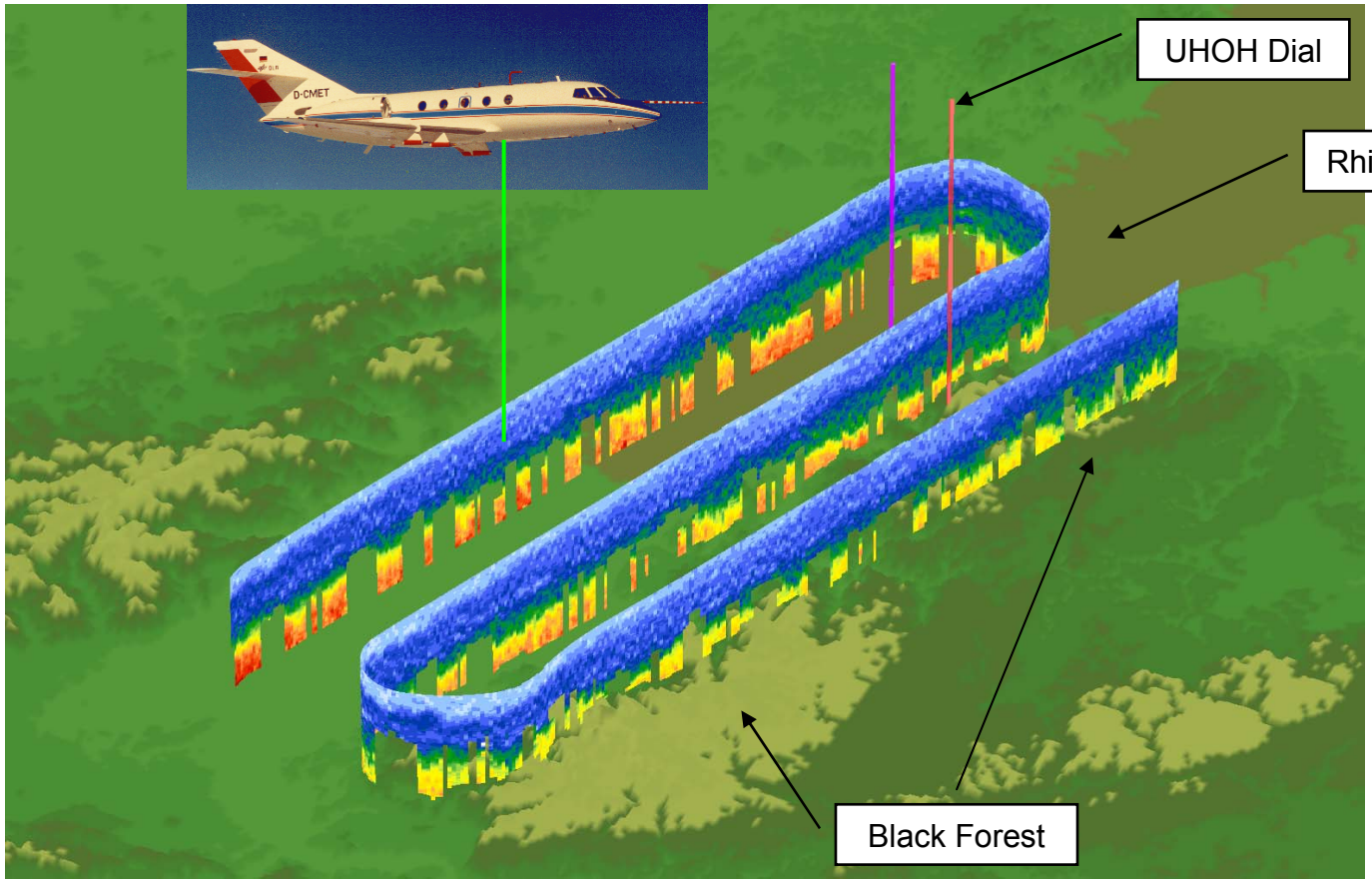
- **Specific humidity is a conserved tracer in absence of clouds**
- **Humidity structures related to transport and mixing processes**
- **Distribution is non-stationary, non-Gaussian, multi-fractal**
- **Fourier spectra not adequate to characterize intermittency**
- **Structure functions of higher order needed (Davis et al, 1994)**

Water Vapour Variability in the Free Troposphere



Smoothness and intermittency quantifiable in bi-fractal parameter space: comparisons with COSMO-DE in hope to improve model parameterisations (Lucas Fischer, PhD student, Univ. Munich)

COPS 2007: Convective and Orographically-induced Precipitation Study



Measure latent heat fluxes over complex terrain

Aerosol, vertical wind and water vapour in the Rhine Valley CBL

backscatter at 936 nm

070730_Leg_D2north

distance (km)

0 10 20 30 40 50 60

altitude asl (km)

2.5 2.0 1.5 1.0 0.5

vertical wind velocity (m/s)

latitude (deg N)

48.3 48.4 48.5 48.6 48.7

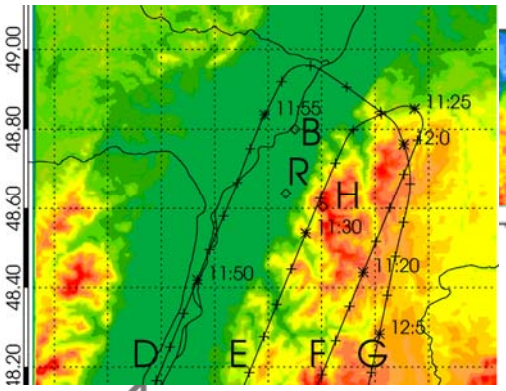
altitude asl (km)

2.5 2.0 1.5 1.0 0.5

water vapour mixing ratio (g/kg)

longitude (deg E)

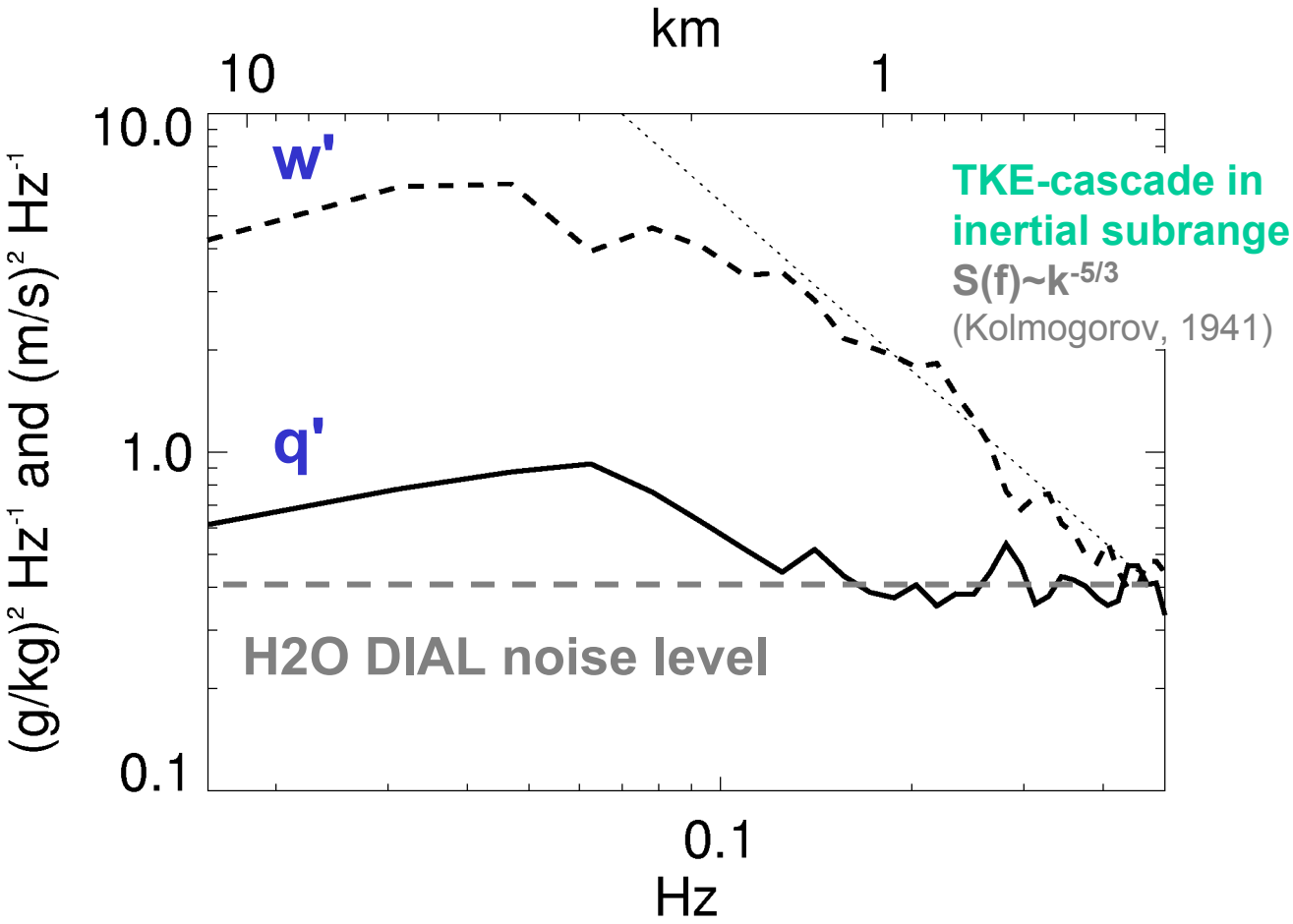
7.70 7.75 7.80 7.85 7.90 7.95



-3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 m/s

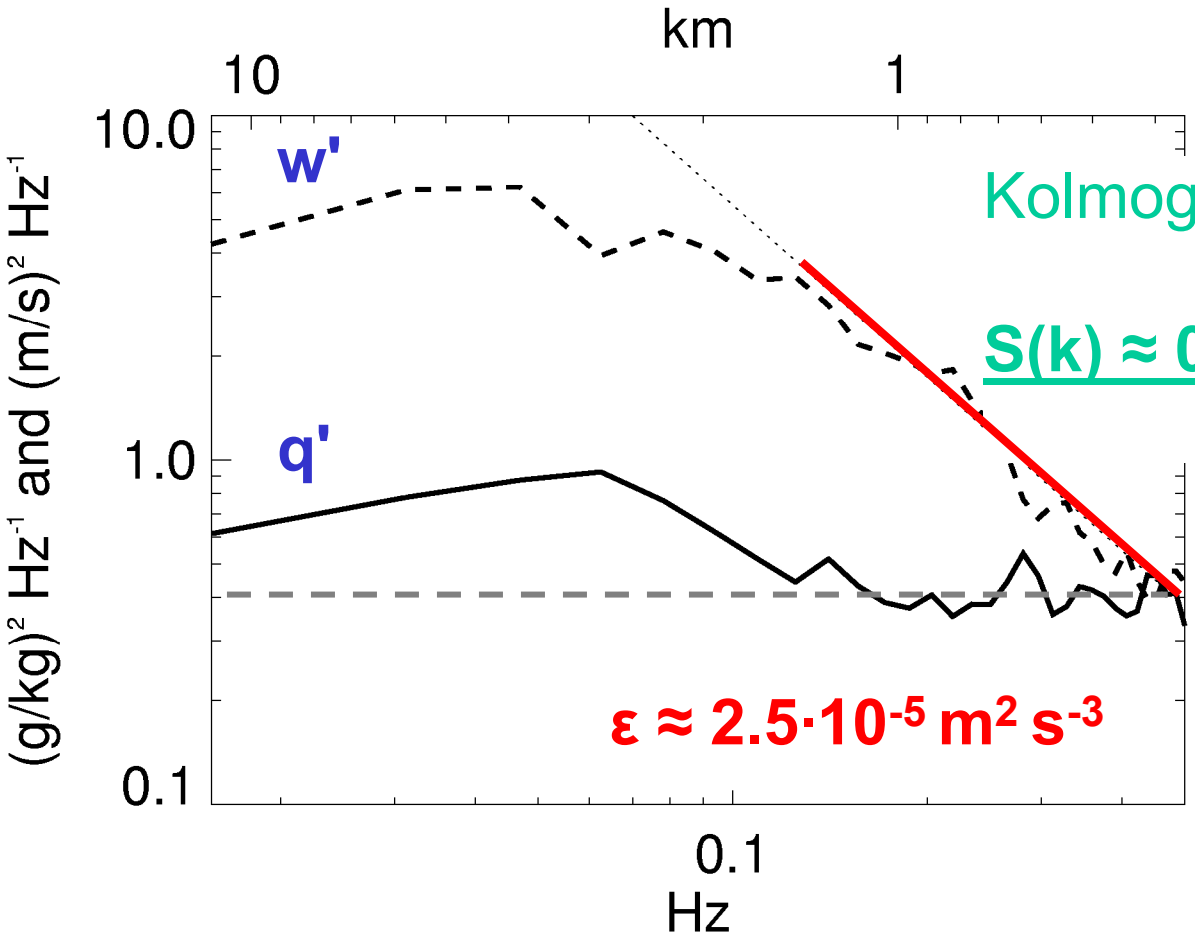
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 g/kg

COPS 30.7.07: Fourier Spectra from Horizontal Series



- **successful comparison with insitu fluxes (Kiemle et al, QJ 2011)**
- **lidar spatial resolution of ~200 m resolves flux dominating eddies**

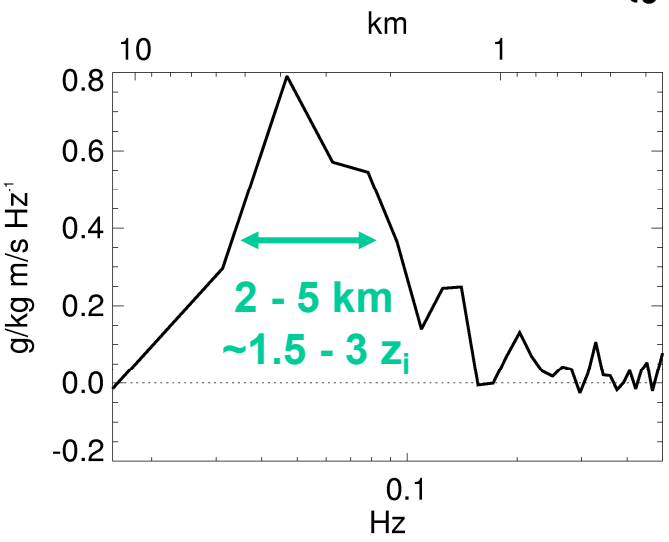
TKE Dissipation Rate Estimation from Wind Lidar

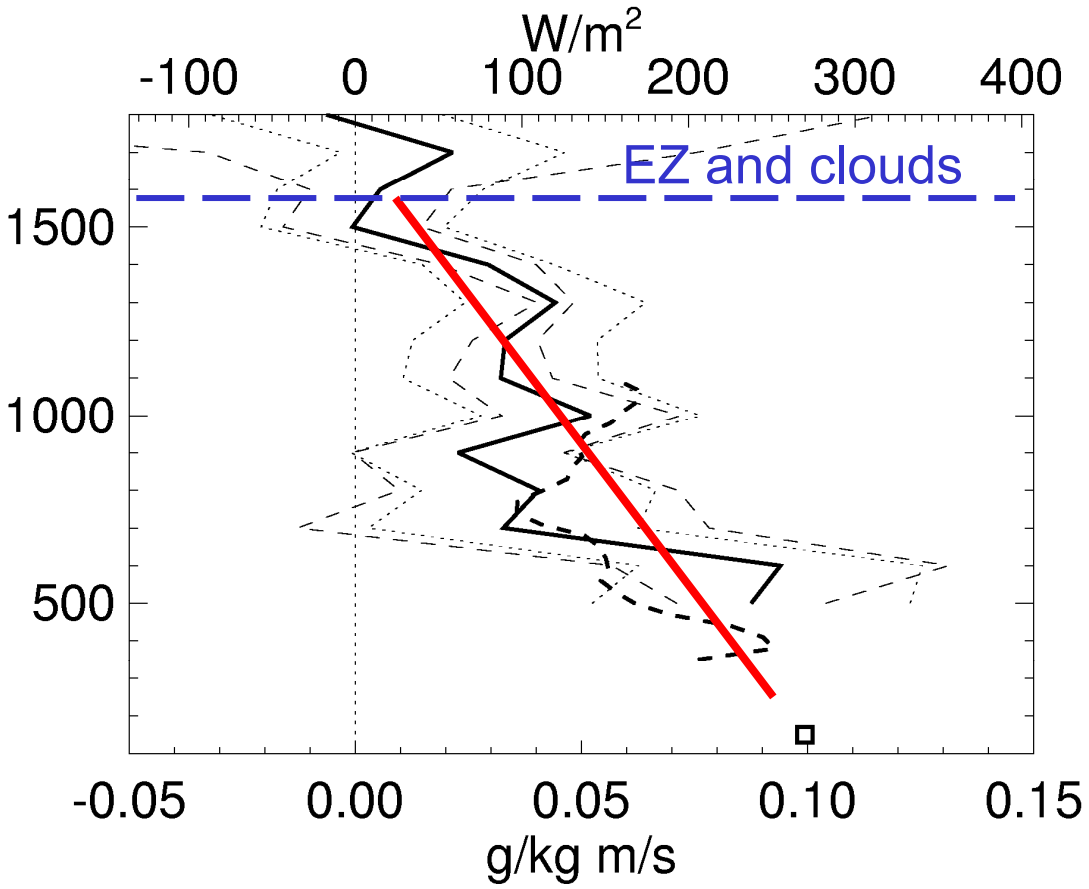


- **successful comparison with insitu fluxes (Kiemle et al, QJ 2011)**
- **lidar spatial resolution of ~200 m resolves flux dominating eddies**

COPS 30.7.07, 14 LT: CBL Latent Heat Flux Divergence

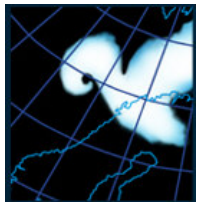
w'q' cospectrum:



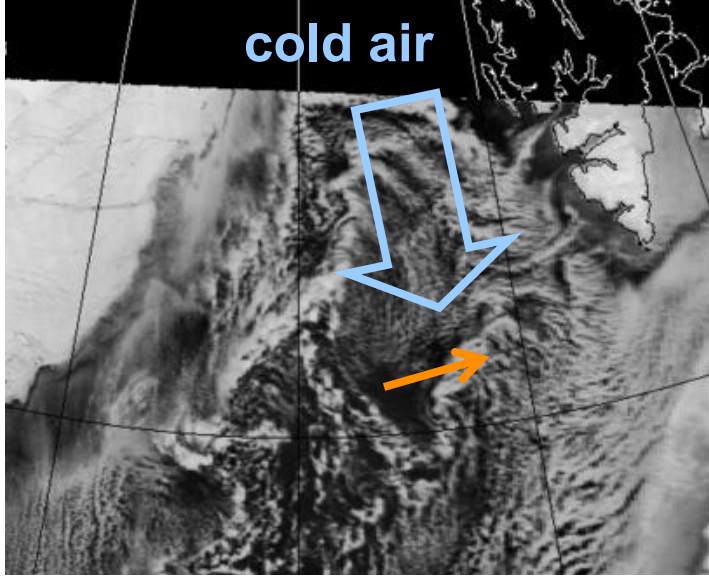


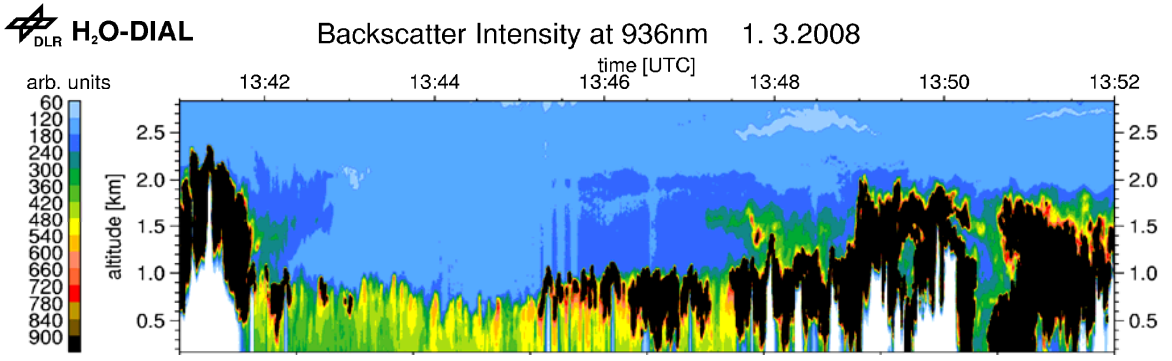
CBL flux divergence: ≈ -0.3 g/kg h^{-1} (± 50 %); advection negligible:

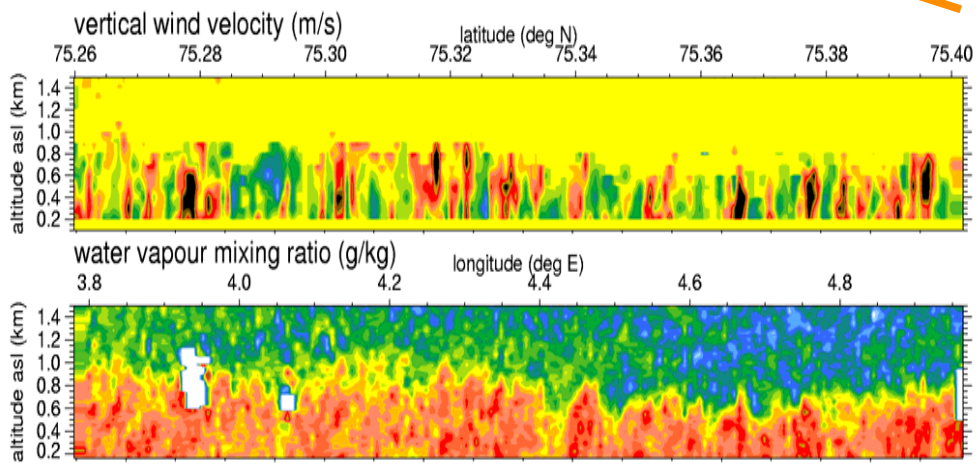
humidity increase by surface evaporation due to previous days' rain.

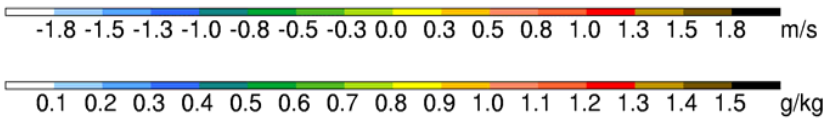


THORPEX-IPY 1.3.2008: cold air convection over Barents sea

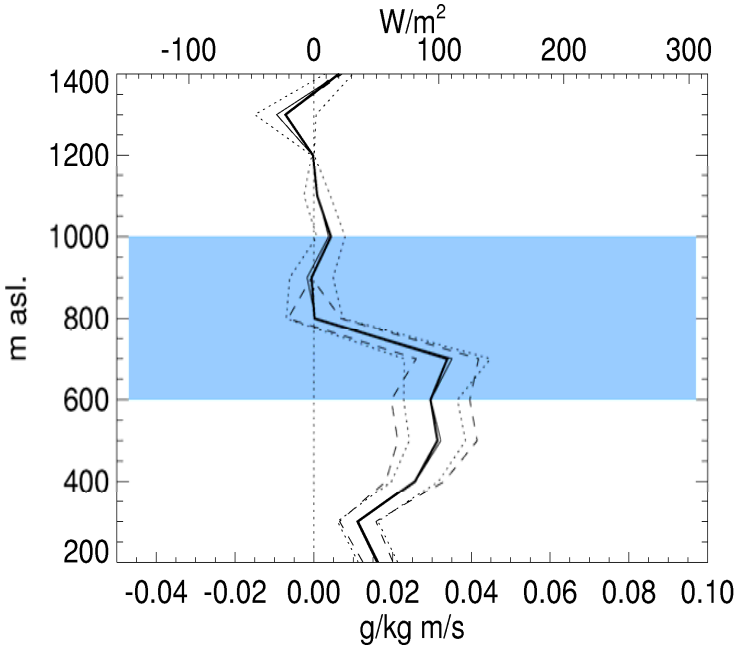








latent heat flux profile:



Conclusions

Airborne wind and water vapor lidar obs for:

- **Quantification of humidity transport in WCB / cyclone inflow and outflow regions,**
- **characterisation of latent heat fluxes near WCB inflow regions, also over sea,**
- **parameterisation of humidity variability in free atmosphere.**